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MINING GEOLOGY IN THE ROSICLARE FLUORSPAR DISTRICT

by

Paul C. Hatmaker

A

T H E S I S

submitted to the faculty of the
SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI
in partial fulfillment of the work required for the

D E G R E E O F
ENGINEER OF MINES

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1927

Approved by

C. V. Forbes

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MINING GEOLOGY in the ROSICLARE FLUORSPAR DISTRICT

The Illinois-Kentucky Fluorspar district is the largest of its kind in the United States and is one of the most important in the world. It lies on either side of the Ohio River in the extreme southeastern part of Illinois and the western part of Kentucky. The mineralized area is relatively small, embracing about 1500 square miles in all. On the Illinois side, the village of Rosiclare is the center of activity. With the exception of Cave-in-Rock, practically the entire production of Illinois comes from the immediate vicinity of Rosiclare and is produced by two companies, the Rosiclare Lead and Fluorspar Mining Co. and the Hillside Fluor Spar Mines.

Fluorspar is of considerable economic importance. In the steel industry and in foundry practice it is extensively used as a flux. It is of especial advantage in the basic open hearth process where it not only lessens the viscosity of the slag but materially assists in the passage of impurities into the slag. It is used in the ceramic industry in the making of certain kinds of opalescent glass. It is also the principal source for the manufacture of hydrofluoric acid and is used to some extent in the aluminum industry.

From a geological standpoint the district as a whole has always attracted considerable attention. The various phases of the historical, structural, and economic geology have been abundantly discussed at different times by the most capable of authorities. In general the country is composed of nearly flat-lying sedimentaries such as limestone, shale, and sandstone, which have been extensively faulted. Some of these faults have been subsequently filled with calcite, fluorite and associated minerals to form typical fissure veins. This injection from deep-seated magmas was probably in the order as named. It is probable that mineralization and faulting were contemporaneous to some extent and that the various minerals intruded overlapped each other in the several stages of vein filling.

ORE SHOOTS

While the mineral fluorite is a non-metallic substance, its nature and occurrence in the Illinois-Kentucky district is such as to place it in the realm of metal mining practice.

All of the known commercial ore bodies in the Rosiclare district occur as vein fillings along fault planes and, in minor instances, as fillings in relief fractures in or near to fault zones. The deposits assume roughly a lenticular and sometimes an ellipsoidal outline, which are often truncated by erosion. There appears to be no established trend for the

direction of the major and minor axes. The major axis may be vertical, horizontal, or inclined. Most of the fault planes along which ore occurs are nearly vertical with the exception of the Blue Diggings fault which dips from 45 to 65 degrees to the east. Widths of fluorspar up to 30' have been known but usually the general width will not be more than 5 or 6 feet in the stoping area.

The horizons of these deposits vary with structural conditions. Along the Rosiclare vein mineralization occurs from the surface down to a known depth of 720' which is the lowest point attained in the Rosiclare mine. The footwall of this vein is almost entirely in the Fredonia-St. Louis limestone members. In general there appears to be a tendency for the most favorable points for ore deposition to be located near or at where a point where one or both walls are limestone. This has been pointed out by Spurr with the suggestion that possibly the Rosiclare sandstone is an important factor in the upward extension and limitation of the ore shoots. And conversely the unfavorable points are very apt to be where both walls are sandstone or shale or both in juxtaposition. There are exceptions to this and instances as in the Daisy #1 ore shoot, where rich mineralization occurs in an apparently unfavorable horizon. This may be accounted for, however, by the fact that this body of ore is close to the trough or zone of greatest

displacement and consequently there is a shattering and distortion of the strata and a pronounced warping of the fault plane which could allow mineralization to penetrate easily a horizon which would otherwise be effectively sealed off. The Daisy #2 and #3 ore shoots south do not extend more than 90' above the 412' level. The downward extension has not yet been established. The Blue Diggings vein where developed from the Daisy 412' level south is intensively mineralized for 600' laterally. This ore goes up, however, only about 50' above the 412' level. Here too the downward extension has not been determined. No mineralization has yet been found at the Daisy mine on the 180' level Blue Diggings vein in a region of juxtaposed sandstone and shale.

It seems improbable that along the Rosiclare fault the ore shoots ever extended much above the present surface as there is an accidental coincidence with the present topographic level and the beginning of shale and sandstone, just above the Rosiclare sandstone. If these ore bodies had had a greater upward extension it seems reasonable to suppose that quantities of gravel spar would now be found at the surface and along the slopes adjoining the outcrop. Quantities of residual wall rock are found but the quantity of gravel spar is insignificant considering the magnitude and richness of the Rosiclare vein. It may therefore be concluded that the horizons of ore deposition bear only an accidental relation to the

present surface and are entirely influenced by geophysical factors of wall characteristics together with unknown conditions of pressure and temperature at the time of formation.

DETAILED OCCURRENCES of ORE

Surface Features and Gravel Deposits:

Surface indications of veins divide themselves into two major groups, those pertaining to the fault itself and those accruing from the mineral constituents of the vein filling. Of the former, the following may be mentioned. The presence of two different kinds of rock at such a relative horizon as to preclude the possibility of there being a natural stratigraphic relation between them is indicative of faulting. The presence of boulders or fragments of quartzite indicate the proximity of a fault as sandstone becomes quartzite at or near a zone of faulting. Occasionally slickensides may be observed in the vicinity of faulting. Often there is a marked relation of topography to fault traces. This is particularly true where a thick sandstone member such as the Cypress sandstone comprises one wall while the opposite wall is an easily eroded shale or limestone. The north Rosiclare fault is strikingly marked in this manner where the hanging wall is Cypress sandstone and the footwall is Lower O'Hara and Fredonia limestone. On the one side there is a pronounced fault scarp and on

the opposite side of the fault there is a fairly low-lying region of sinks. The vein itself follows near the lower part of the scarp slope.

There are also instances where strata may be noted in an extremely distorted position or nearly on edge. This of course is the drag material adjacent to the plane of movement. It may be noted even in soft clays which are residual from the weathering of shale or limestone, the original bedding planes still preserving their faint markings. Often where a fault crosses a country road the course will be manifested by a serious mudhole often extensive in proportions and slow to dry up. This feature sometimes gives a clue when other points are obscured.

Of the vein-matter surface indications the most certain of course is the presence of gravel spar in the soil or sub-soil. Due to the great resistance which fluorspar offers to weathering, this condition is sometimes easily observed. More often, however, the actual ore is hidden under a mantle of soil and recourse must be made to other considerations. One of the more important is the presence of red- or brick-colored dirt along the top of a vein. This is often blinded by the loess which is prevalent for a depth of 3 or 4 feet but the red stains can usually be detected in washes and cuts. This discoloration is no doubt the result of oxidation of the small amount of iron

sulfids in the vein material with a subsequent concentration of the iron oxide so obtained, and from the wall rock in which it occurs to a slight extent, along the course of the vein outcrop.

In prospect work veins are located therefore approximately by the several characteristics and criteria appertaining to faults and more precisely by indications arising from the disintegration of the vein constituents.

Gravel spar may be classed as the zone of secondary enrichment. It is the result of weathering and is the product of Nature's methods of concentration and beneficiation. Seldom does it extend more than a few feet downward and often spreads out in mantle form in the blanket type of deposit, thinly covered with a few inches of soil. As the gang material consists mostly of clay and dirt, this ore needs only to be washed in a log washer to render a marketable product. It is often the case that a small vein too narrow to be profitably worked in the unaltered zone will form a gravel deposit of remarkable proportions representing the concentration and deposition of hundreds of feet of vein filling.

Below this surface zone the fluorspar occurs solid except for fracturing or shattering resulting from movement and pressure. Close to the surface the solid spar may be in mud and clay walls but farther down the walls become solid, tightly encasing the ore shoot. Galena, which is argentiferous, is most

abundant near the surface and calcite usually predominates in the lower horizons. Other associated minerals are pyrite and chalcopyrite, marcasite, sphalerite and even more rarely siderite and barite. The amount of this entire group is insignificant, however. While all of these minerals occur to a more or less extent along with and in the unaltered fluorspar, they also have a secondary habit. Near the surface galena occurs in larger crystals more often along either wall or in fractures. Crystals of fluorspar are found in vugs with superimposed crystals of calcite and sulfids of iron and copper.

Local Structural Features:

In order to obtain a clear conception of the several local structural features, it is first necessary to consider some of the broader phases of the general structure which greatly influence the more local characteristics. Reference is made to the accompanying geological cross-sections. It will be noted that above the Fredonia limestone, alternating layers of sandstone, shale, and more rarely limestone, predominate. This condition materially affects the nature of the walls of the ore shoots and, as has already been mentioned, to some extent the distribution of the ore.

The faults themselves are hinge faults. Considering a longitudinal section along a fault, there will be found a locality of maximum displacement or trough. Away from this

trough the displacement becomes less until finally the fault is no longer discernible. In some cases, in passing away from the trough, the fault splits up into several lesser faults, they in turn merging at last into a shear zone with no well-defined planes of movement.

That the movement along these faults did not occur all at the same time or in the same direction is evidenced by the presence of often several different and distinct slip planes between the main walls. Striations can be observed on slickensides, vertical, horizontal, or inclined. Sometimes the slip planes will consist of an inch or more of shaly gouge and selvage with either fluorspar or calcite on either or both sides. This condition indicates several distinct phases of movement and also of mineralization. A considerable degree of care must be used during stoping and also when any headings are being driven in the vein to make sure that the true or main fault is the one being followed and that the apparent wall is not a false wall masking parallel ore bodies.

At times these slips encompass masses of country rock or horses as they are known. For the most part these are of short extent and tend to strike diagonally across the vein from one wall to the other. These are also apt to mask ore bodies. In following an ore shoot along the vein the walls may pinch rapidly, narrowing the ore body to a foot or less. Further driving discloses that the ore continues, suddenly widening and perhaps extending alongside of the old working but offset

a few feet and blinded by the horse or false wall. Where the latter is of limestone it is usually somewhat impregnated with fluorite. Sandstone and shale, however, do not so lend themselves to enrichment. Sandstone may be brecciated and subsequently healed or recemented with fluorite but shale as a rule is almost completely impervious.

As previously mentioned, the feathering out of faults is a common condition. The main plane of fracture, as the throw decreases, tends to divide into several fractures each with a diminishing displacement and consequently with a lesser disturbance of the walls. Finally a point is reached where only a shear zone marks the beginning or ending of a fault thousands of feet long.

This in reality is step faulting on a smaller scale, a direct result of strain relief, even as the larger faults are relatively larger steps between the major faults. The entire region of faulting is the natural readjustment in the earth's crust where greater strains and stresses are relieved by more marked and drastic movement while lesser strains naturally result in correspondingly lesser manifestations.

Current mining practice conforms to a considerable extent to these conditions. Near the surface where the walls are apt to be greatly weathered while the fluorspar remains solid and where shale predominates on the hanging wall, square-set mining is usually adopted. Back filling is seldom resorted

to except as a convenient method of waste disposal. Where the walls are solid shrinkage stopes are regularly employed. Occasionally stulls are placed in these filled stopes to support slabs of shale and selvage sp as to minimize dilution from the wall material. When the sequence of strata is accurately known on either side of an ore body a mining scheme can sometimes be planned so as to combine these methods for the greater efficiency of the ore breking operation.

EXPIORATION:

Exploration and prospecting may be divided into two main parts, surface and sub-surface work. Each has its individual problems which must be attacked in different ways. As far as possible work from these two angles are correlated to attain the ultimate goal of actual location or ore reserves.

Surface exploration and prospecting consist almost entirely in the observation of the several features common to surface deposits as noted before. This is followed by test pits and shallow trenches along the course of the vein or fault. Prospect shafts may be sunk by hand with a windlass to a practical depth of 50'. This is usually sufficient to reach solid walls and consolidated vein material.

By far the most important exploration work is done at depths which may be from fifty to five hundred feet or more below the surface of the ground. The general course of the

faults is usually rather well defined and the problem is to locate the various ore shoots with a minimum of dead work.

The two methods most commonly employed in the district are diamond drilling and exploratory drifts and cross-cuts. Preference is given to the latter except for strictly wild-cat work where little is known of the kind or extent of mineralization. Diamond drilling presents several unfavorable characteristics which minimize the usefulness of this sort of practice. These are due principally to the physical characteristics and mode of occurrence of the ore shoots themselves. As the ore is found in separate and distinct lenses or shoots along the faults, it is entirely possible to miss them completely with a drill and to draw erroneous conclusions from a drilling campaign. This has happened in several instances in the district and is one of the greatest dangers of drilling. Another great disadvantage in drilling is that no conception of size or extent of an ore body is available. A small pocket only a few feet in extent may give exactly the same core that an ore body containing many thousands of tons. Then too the course of a hole may vary many degrees from the determined course which may cause excessive deadwork when development is engaged in. Another minor objection is caused by the open solution channels in the country rock and the presence of mud courses and pockets which may cause considerable trouble in going thru them with a drill hole. Many of these objections

may be partially or completely eliminated by decreasing the distance between the holes and elaborate surveying of the hole itself but when this is done the cost of the work approximates the cost of drifts and crosscuts and results in a doubling of exploration and development costs.

Suppose that a fault is known to exist approximately parallel to and a few hundred feet away from an operating mine which is served by the usual drifts and shafts. Ore is thot to exist along this second fault and an exploration campaign is inaugurated. Shall drilling be done prior to crosscutting? For the cost of the crosscut, four holes can be drilled. If ore is found by drilling, the crosscut will then be driven so that the cost of drilling is actually an excessive item in the final cost of the ore obtained. If no ore is found altho some mineralization is encountered by drilling, there is always the possibility that the ore bodies were missed and that it is unwise to condemn the entire stretch of ground on the results obtained by four holes. In that even more drilling is resorted to or the crosscut is driven with the resulting duplication of effort and expense. In cases of this nature it would appear wise to confine exploration work to the driving of crosscuts with subsequent drifting.

Where a vein is developed partially by a shaft and drifts at the several levels it is established policy to continue exploration along the vein by the driving of drifts thru the

pinches encountered between ore bodies. This is finally carried to a point where the property lines stop further work or until the fault commences to feather out and become indistinct.

There are times, however, when diamond drilling justifies the use of this method. Where the time element is more important than the added cost such as where a property is taken on a short-time option or where it is desired quickly to explore a certain territory before deciding upon an extensive development campaign, drilling may be resorted to with a reasonable degree of success. Its shortcomings must always be remembered and sufficient allowance made for them.

Drilling is also advantageous when the course of a vein is not known within a few hundred feet owing to the surface features being entirely obscured by residual material and loess. In this case drilling properly interpreted should fully justify itself by the saving in subsequent deadwork.

The chief function of mining geology is to assemble the facts as exploration work is carried along so that complete data are available at all times as to the exact conditions existing at the time. Theory must come after the facts are assembled. The questions to be determined are the following: What is the strata sequence of the walls at a given point? As a drift progresses along a fault is the displacement increasing or diminishing? If a crosscut or a winze or a shaft

is to be started and a contract is to be let, what will be the rock encountered and what will the operating conditions be? Often these data materially affect the unit contract price for a given job. From them can eventually be reared a true picture of conditions. Gradually predictions may be made with increasing certainty, finally resulting in greater efficiency of operation and a lowered cost of mining.

FUTURE of MINING GEOLOGY in the DISTRICT

Mining geology will undoubtedly play an even greater part in future exploitations than it has in past operations. As is the case in most of the older mining camps, the ore bodies most readily accessible are being gradually exhausted. Consequently exploration and development work increases a little every year. There will come a time when, at a given value for finished product, it will no longer be possible to carry on extensive exploration work. From then onward final exhaustion at least from a commercial standpoint will come with astonishing rapidity. It is in the continual postponement of this time, perhaps an indefinite postponement so far as present generations are concerned that mining geology will play a virile and important role.

The problems which are looming on the horizon are interesting ones and offer grounds for much speculation and debate. Below the calcite in which most of the ore bodies apparently

bottom, is there more calcite or may there be additional horizons of fluorspar? The latter will probably be found to be the case. The importance of this question may be minimized somewhat because of the direct increase in the amount of mine water which must be pumped with added depth. There exists a dead line below which it would not be profitable to carry on mining operations. So while the question of downward extension of ore shoots is apt to receive considerable attention especially from a strictly theoretical standpoint, its general importance except for a few individual cases is probably somewhat overestimated owing to the automatic limiting action of the water increment.

What of the many faults thruout the district which apparently are not mineralized? There would seem to be a strong probability that many of these will some day be found to contain commercial ore bodies either at point now concealed by surface residuum or at some lower horizon than the one accidentally revealed to us at the present surface. It is not impossible that the great, richly-mineralized Rosiclare vein itself, the richest in the district, would be barren and non-productive had five hundred feet, perhaps much less, of overlying sediments been left above the present surface. Many of the lesser faults are known to be mineralized to some extent. It is quite possible that commercial ore bodies may be found in these and that they will be the mines of the future, when the present ones are

exhausted.

Present day methods of prospecting will no doubt be supplanted in the future by more scientific ones. The torsion balance may someday be used to detect the infinitesimal changes in the gravitational field of the earth caused by bodies of fluorspar. The science of geo-physics and electrical prospecting is advancing rapidly and will probably be the basis for future prospect work.

The future of the district may be considered, from the viewpoint of supply, to be sound and optimistic for many years to come. It is not unreasonable to suppose that new discoveries thru advanced methods will at least keep pace with the current consumption. This after all will be governed, not so much by the limitations of science, but by the intensity and earnestness of the demand for fluorspar.

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